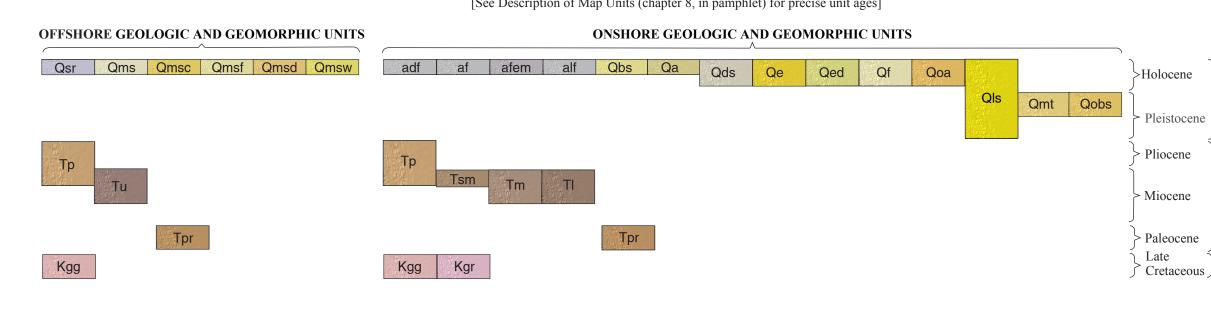


CORRELATION OF MAP UNITS [See Description of Map Units (chapter 8, in pamphlet) for precise unit ages]



LIST OF MAP UNITS

[See Description of Map Units (chapter 8, in pamphlet) for complete map-unit descriptions] OFFSHORE GEOLOGIC AND GEOMORPHIC UNITS Marine shelf deposits, rough seafloor (late Holocene)—Irregular "lumps" on seafloor; interpreted as marine debris; possibly related to either one or more shipwrecks or

biological "hardgrounds" **Qms** Marine nearshore and shelf deposits (late Holocene)—Mostly sand; ripples common **Qmsc** Coarse-grained marine nearshore and shelf deposits (late Holocene)—Coarse sand, **Qmsf Fine-grained marine shelf deposits (late Holocene)**—Mostly mud to muddy sand Qmsd Marine shelf scour depressions (late Holocene)—Inferred to be coarse sand and gravel, Marine sediment-wave deposits (late Holocene)—Predominantly sand; formed by strong tidal currents that flow around Point Reyes headland and into Drakes Bay Purisima Formation (Pliocene and late Miocene)—Marine siltstone interbedded with

mudstone and sandstone; locally contains diatomite Sedimentary rocks, undivided (Pliocene to middle Miocene)—May consist of the Monterey Formation (mapped onland as unit Tm), the Santa Margarita Sandstone (mapped onland as unit Tsm), and the Purisima Formation (unit Tp) Tpr Point Reyes Conglomerate of Galloway (1977) (early Eocene)—Marine arkosic sandstone; also includes basal granitic-clast conglomerate Kgg Point Reyes Granodiorite, porphyritic facies (Late Cretaceous)—Highly fractured

ONSHORE GEOLOGIC AND GEOMORPHIC UNITS

[Bedrock units compiled from Clark and Brabb (1997) and Wagner and Gutierrez (2010); unit ages, which are from these sources, reflect local stratigraphic relations. Quaternary units compiled from Witter and others (2006) and Wagner and Gutierrez (2010), with some additional mapping by M.W. Manson (this report); in addition, some units modified by M.W. Manson on basis of analysis of 2012 Artificial-dam fill (late Holocene)—Earth- or rock-fill dams, embankments, and levees;

constructed to impound land-locked water bodies af Artificial fill (late Holocene)—Engineered and (or) nonengineered Artificial fill over estuarine mud (late Holocene)—Material deposited by humans over **Artificial-levee fill (late Holocene)**—Constructed levees bordering rivers, streams, sloughs, and islands **Beach-sand deposits (late Holocene)**—Active beaches in coastal environments; may form veneer over bedrock platform Alluvial deposits, undivided (late Holocene)—Fluvial sediment; judged to be latest Holocene age (less than 1,000 years old)

Dune sand (Holocene)—Active and recently stabilized dunes in coastal environments **Estuarine deposits (Holocene)**—Heterogeneous mixture of coarse and fine estuarine sediment; deposited in Drakes Estero and Estero de Limantour **Estuarine-delta deposits (Holocene)**—Heterogeneous mixture of coarse and fine estuarine sediment; deposited in delta at mouths of tidally influenced coastal streams, where fresh water mixes with seawater Alluvial fan deposits, undivided (Holocene)—Sediment deposited by streams emanating from mountain canyons onto alluvial valley floors or alluvial plains **Alluvial deposits, undivided (Holocene)**—Alluvium deposited in fan, terrace, or basin

Landslide deposits (Holocene and Pleistocene)—Weathered rocks and soil. Internal contacts differentiate individual landslide bodies Marine-terrace deposits (late Pleistocene)—Sand, gravel, and cobbles; deposited on marine-abrasion platforms and later uplifted to present-day elevations along coast Older beach-sand deposits (late Pleistocene?)—Reddish-brown, friable sand and fine Purisima Formation (Pliocene and late Miocene)—Siltstone interbedded with mudstone and sandstone; locally contains diatomite

T_{SM} Santa Margarita Sandstone (late Miocene)—Massive arkosic sandstone Monterey Formation (late and middle Miocene)—Thin-bedded siliceous shale, interbedded with arkosic sandstone Laird Sandstone of Clark and others (1984) (late and middle Miocene)—Arkosic sandstone that contains basal granitic-boulder conglomerate Point Reyes Conglomerate of Galloway (1977) (early Eocene)—Marine arkosic sandstone; also includes basal granitic-clast conglomerate Point Reyes Granodiorite, porphyritic facies (Late Cretaceous)—Contains potassium-feldspar phenocrysts that average 2 to 3 cm in length (maximum, 5 cm) Kgr Granodiorite and granite of Inverness Ridge (Late Cretaceous)—Granodiorite and

EXPLANATION OF MAP SYMBOLS

block; D, downthrown block **Folds**—Dashed where location is approximate, dotted where location is concealed

Significant inflection (change in dip) within limb of fold

granite; commonly includes aplite and alaskite dikes

———— Contact—Solid where location is certain, dashed where location is approximate

Approximate modern shoreline—Defined as Mean High Water (MHW) (+1.46 m), North American Vertical Datum of 1988 (NAVD 88) 3-nautical-mile limit of California's State Waters **Area of "no data"**—Areas beyond 3-nautical-mile limit of California's State Waters were

not mapped as part of California Seafloor Mapping Program DISCUSSION

Marine geology and geomorphology were mapped in the Offshore of Point Reyes map area from approximate Mean High Water (MHW) to the 3-nautical-mile limit of California's State Waters. MHW is defined at an elevation of 1.46 m above the North American Vertical Datum of 1988 (NAVD 88) (Weber and others, 2005). Offshore geologic units were delineated on the basis of integrated analyses of adjacent onshore geology with multibeam bathymetry and backscatter imagery (sheets 1, 2, 3), seafloor-sediment and rock samples (Reid and others, 2006), digital camera and video imagery (sheet 6), and high-resolution seismic-reflection profiles (sheet 8). Aerial photographs taken in multiple years were used to map the nearshore area (0 to 10 m water depth) and to link the offshore and onshore Onshore bedrock mapping is compiled from Clark and Brabb (1997) and Wagner and Gutierrez

(2010); unit ages, which are derived from these sources, reflect local stratigraphic relations. Onshore Quaternary mapping is compiled from Witter and others (2006) and Wagner and Gutierrez (2010), with some additional mapping by M.W. Manson (this report); in addition, some units are modified by M.W. Manson on the basis of analysis of 2012 lidar imagery. The onshore part of the Offshore of Point Reyes map area contains the southwestern part of the Point Reyes peninsula, which is located entirely west of the San Andreas Fault, the transform boundary between the Pacific and North American plates. The Point Reyes peninsula is composed of Late Cretaceous granitic rocks of the Salinian block that are overlain by Tertiary marine sedimentary rocks (Page, 1982). The Salinian block, an allochthonous (that is, out of place) tectonostratigraphic terrane, was brought north to its present-day position by right-lateral slip along the San Andreas Fault system. Since late Miocene time, the Point Reyes peninsula has been offset about 155 km along the San Gregorio and San Andreas Faults from the Monterey peninsula, where it was adjacent to Point Lobos (Greene and Clark, 1979; Clark and others, 1984; Dickinson and others, 2005). The geology and geomorphology of the Offshore of Point Reves map area are the result of the interplay between tectonics, sea-level rise, local sedimentary processes, and oceanography. The Point Reyes Fault Zone, which runs through the offshore part of the map area, is a curvilinear reverse fault zone (Hoskins and Griffiths, 1971; McCulloch, 1987; Heck and others, 1990; Stozek, 2012) that likely connects with the west strand of the San Gregorio Fault Zone farther south (Ryan and others, 2008), making it part of the San Andreas Fault system. The Point Reyes Fault Zone is characterized by a 5- to 11-km-wide zone that is associated with two main fault structures: the Point Reyes Fault, and also a west strand mapped offshore of the Point Reyes peninsula (fig. 1).

Tectonic influences that affect shelf morphology and geology are local faulting, folding, uplift, and subsidence. Offshore of the Point Reyes headland, granitic basement rocks are offset vertically (north side up) about 1.4 km on the reverse-slip Point Reyes Fault Zone (McCulloch, 1987); this uplift, combined with west-side-up offset on the San Andreas Fault Zone (Grove and Niemi, 2005), has resulted in uplift of the Point Reyes peninsula and the adjacent shelf (both the Bodega Head-Tomales Point shelf, north of the map area, and the Bolinas shelf; see sheet 9). The west strand of the Point Reyes Fault Zone is defined by a broad anticlinal structure, which is visible in both industry and high-resolution seismic-reflection data (see sheet 8), and it exhibits the same sense of vergence (north the Point Reyes Fault Zone has resulted in a distinct bathymetric gradient across the Point Reyes Fault Zone: an emergent or shallow bedrock platform is present to the north and east of the fault zone, and a deeper, submerged bedrock platform lies to the south.

Late Pleistocene uplift of marine terraces on the southern Point Reyes peninsula suggests active deformation of offshore structures west of the San Andreas Fault Zone (Grove and others, 2010). The Point Reyes Fault and related structures may be responsible for this recent uplift of the Point Reyes peninsula; however, both the distribution and age control of Pleistocene strata are not well constrained in the Offshore of Point Reyes map area, and, thus, it is difficult to directly link the onshore uplift with the offshore Point Reyes Fault structures. Pervasive stratal thinning within inferred uppermost Pliocene and Pleistocene (that is, post–Purisima Formation) deposits within the anticline that is above the west strand of the Point Reyes Fault Zone (see sheet 8) suggests Quaternary active shortening of the curvilinear, northeast- to north-dipping Point Reyes Fault Zone. Lack of clear deformation in the uppermost Pleistocene and Holocene deposits suggests that activity along the Point Reyes Fault Zone has ceased or slowed since about 21,000 years ago. Although the cumulative, post-Miocene slip rate on the Point Reyes Fault Zone in the map area is poorly constrained, it is estimated to be 0.3 mm/yr on the basis of vertical offset of granitic basement rocks (McCulloch, 1987; Wills and others, 2008).

With the exception of the bathymetric gradient across the Point Reyes Fault, the offshore part of the map area is characterized largely by a relatively flat (less than 0.8°) bedrock platform. The continental shelf is quite wide in this area; the shelf break is located west of the Farallon high (see fig. 1), about 35 km offshore. Sea level has risen about 125 to 130 m during the last about 21,000 years (see, for example, Lambeck and Chappell, 2001; Peltier and Fairbanks, 2006), leading to a broadening of the continental shelf, the progressive eastward migration of the shoreline and wave-cut platform, and the associated transgressive erosion and deposition of sediment (see, for example, Catuneanu, 2006). Land-derived sediment was carried into this dynamic setting and then subjected to Pacific Ocean wave energy and strong currents before deposition or offshore transport.

Much of the inner shelf bedrock platform is composed of Tertiary marine sedimentary rocks, which are underlain by granitic and metamorphic basement rocks of the Salinian block, including the Late Cretaceous Point Reyes Granodiorite, porphyritic facies (unit Kgg), which crops out on the seafloor south of the Point Reyes headland. Offshore outcrops of unit Kgg appear to be complexly fractured, similar to onshore exposures, and they have a distinctive massive, bulbous texture that is visible in multibeam imagery. Tertiary strata that overlie the granitic rocks form the core of the Point Reyes Syncline (Weaver, 1949); these strata include the lower Eocene Point Reyes Conglomerate (unit Tpr), the middle and upper Miocene Monterey Formation (unit Tm), the upper Miocene Santa Margarita Sandstone (unit Tsm), and the upper Miocene and Pliocene Purisima Formation (unit Tp). Similarities in age, petrology, petrography, geochemistry, and depositional history indicate that the Point Reyes Conglomerate was deposited in the same submarine canyon system as the Carmelo Formation (Burnham, 2009), mapped about 180 km to the south, and that the two units were subsequently offset along the San Andreas Fault system (Clark and others, 1984; Burnham, 1998; Burnham, 2009). The Point Reyes Conglomerate, whose exposures on the seafloor west of the Point Reyes headland are adjacent to onshore outcrops on the headland, has a relatively massive texture in which few bedding planes are visible, and the strata are highly fractured. On the basis of stratigraphic correlations from both seismic-reflection data and onshore wells, combined with multibeam bathymetry imagery, we infer that rocks of the lower Eocene Point Reyes Conglomerate also extend at least 6 km to the northwest from onshore exposures on the Point Reyes headland. Geologic mapping onshore by Clark and Brabb (1997) indicated that the Santa Cruz Mudstone (unit Tsc) is not present within the onshore Tertiary section in the map area, and it also suggested that the unit is not present within the adjacent offshore stratigraphy either. Data from offshore wells just south of the Point Reyes Fault indicate that a significant amount of the Santa Cruz Mudstone is present within the Tertiary section, suggesting that uplift along the Point Reyes Fault during the late Miocene may explain why no Santa Cruz Mudstone is present directly north of the fault. In the Offshore of Point Reyes map area, the undivided sedimentary rocks unit (Tu) represents seafloor outcrops of a middle Miocene to Pliocene sequence that overlies the Point Reyes Conglomerate (unit Tpr); this undivided unit may include strata of the Monterey Formation (unit Tm), the Santa Margarita Sandstone (unit Tsm), and the Purisima Formation (unit Tp) . Seafloor exposures of unit Tu are characterized both by their distinctive rhythmic bedding in which beds are dipping and by a mottled texture in which those beds become flat lying.

gravel, and cobbles (units Qmsc and Qmsd). Coarser grained sands and gravels (units Qmsc and Qmsd) are recognized primarily on the basis of bathymetry and high backscatter (sheets 1, 2, 3). The emergent bedrock platform northwest and west of the Point Reyes headland is heavily scoured, and large areas of unit Qmsc and associated unit Qmsd are present. Both units Qmsc and Qmsd typically have abrupt landward contacts with bedrock, and they form irregular to lenticular exposures. Contacts between units Qmsc and Qms typically are gradational. Unit Qmsd typically is mapped as erosional lags in scour depressions (see, for example, Cacchione and others, 1984) that are bounded by relatively sharp or, less commonly, diffuse contacts with the horizontal sand sheets of unit Qms. These depressions typically are a few tens of centimeters deep and range in size from a few tens of square meters to more than 1 km². Such scour depressions are common along this stretch of the California coast (see, for example, Cacchione and others, 1984; Hallenbeck and

Modern nearshore sediments are mostly sand (unit Qms and Qmsw), as well as a mix of sand,

others, 2012; Davis and others, 2013) where offshore sandy sediment can be relatively thin (and, thus, is unable to fill the depressions) owing to lack of sediment supply from rivers and also to significant erosion and offshore transport of sediment during large northwest winter swells. Such features have been referred to as "rippled scour depressions" (see, for example, Cacchione and others, 1984) or "sorted bedforms" (see, for example, Murray and Thieler, 2004; Goff and others, 2005; Trembanis and Hume, 2011). Although the general areas in which both unit Qmsd scour depressions and surrounding Qms sand sheets are found are not likely to change substantially, the boundaries of the unit(s) likely are ephemeral, changing seasonally and during significant storm events. An area of high backscatter (see sheet 3) and rough seafloor (unit Qsr) is notable in that it includes several small (less than about 20,000 m²), irregular "lumps" that have as much as 1 m of positive relief above the surrounding seafloor. Southeast of the Point Reyes headland, unit Qsr is mapped in water depths of between 50 and 60 m, and the orientation of the individual lumps ranges from randomly distributed to west trending. Seismic-reflection data (see, for example, fig. 4 on sheet 8) reveal that this lumpy material rests on several meters of uppermost Pleistocene to Holocene sediment and, thus, is not bedrock outcrop. We interpret it as marine debris, possibly derived from the more than 60 shipwrecks that occurred offshore of the Point Reyes peninsula between 1849 and 1940 (National Park Service, 2012). It also is conceivable that this lumpy terrain consists of biological "hardgrounds" (that is, groups of fauna on the seafloor, which have rigid, often calcareous, shells that exhibit high reflectivity, similar to lithified rock). Note that the video ground-truthing data that cross unit Qsr near the Point Reyes headland (see Box D on sheet 6) were of insufficient quality to distinguish between these two alterna-

A transition to finer grained marine sediments (unit Qmsf) is seen south of the Point Reves headland at depths of about 50 to 60 m; however, directly south of Drakes Estero and Estero de Limantour, both backscatter data and seafloor-sediment samples (Chin and others, 1997) suggest that fine-grained sediments extend into water depths as shallow as 30 m. Unit Qmsf, which commonly is extensively bioturbated, primarily consists of mud and muddy sand. These fine-grained sediments are inferred to have been derived either locally from Drakes Estero and Estero de Limantour or from the San Francisco Bay to the south (about 40 km south of the map area) via the predominantly northwestward flow (Noble and Gelfenbaum, 1990).

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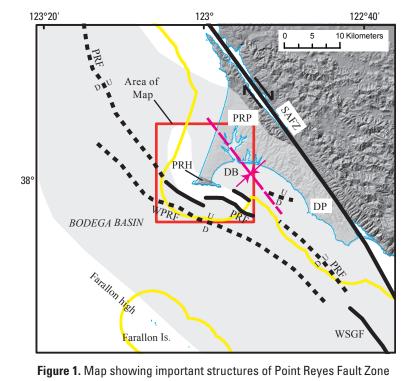
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offshore of Point Reyes peninsula. Fault structures are based on interpretation of both deep-penetration multichannel and USGS shallow minisparker seismic-reflection data. Faults are shown by thick black lines: solid lines show faults that are imaged in shallow minisparker data; dashed lines indicate buried faults that show no visible offset in shallow minisparker data; U, upthrown block; D, downthrown block; paired arrows indicate relative motion on strike slip fault. Dashed magenta line shows approximate axis of Point Reyes Syncline. Gray shading shows late Tertiary Bodega Basin (modified from McCulloch, 1987). Red box shows Offshore of Point Reyes map area. Yellow line shows limit of California's State Waters. Abbreviations: DB, Drakes Bay; DP, Double Point; PRF, Point Reyes Fault; PRH, Point Reyes headland; PRP, Point Reyes peninsula; WPRF, west strand of Point Reyes Fault Zone; WSGF, west strand of San Gregorio Fault









